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GYPSY MOTH CONTROL PROJECT

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APPRAISAL OF DAMAGE BY THE GYPSY MOTH IN NEW ENGLAND

1933 - 1952

By
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* * December 1952 * *

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DAMAGE BY THE GYPSY MOTH IN NEW ENGLAND 1933-52

1. GENERAL

This study is an attempt to evaluate damage by the gypsy moth in the New England States from 1933-52 inclusive in terms of timber and related values. Chief emphasis has been placed on stumpage losses due to mortality and to loss in growth as a direct result of gypsy moth defoliation. Consideration has also been given to intangible losses which cannot be clearly expressed in dollars and cents, but which are essential at arriving at a true picture of the extent of damage.

Timber damage is largely confined to the oak and pine-oak types. It centers primarily on the oaks which suffer varying degrees of mortality depending on the severity and frequency of the attacks and on factors of site, drought, other insects and diseases, and late frosts.

A single complete stripping will rarely cause severe mortality in the oaks unless complicated by a second defoliation due to a late frost,or by overmaturity, drought, or other reasons. It generally takes more than one year of heavy successive stripping for mortality to be marked--an exception sometimes occuring when mature black oak stands are visited for the first time with a heavy defoliation.

Resistance to killing is greatest in white oak and chestnut oak and least in the red, scarlet, and black oaks in that order. Killing of white pine and hemlock occurs in some instances, but is not as widespread as that of the oaks.

Killing of other favored food species such as grey birch and aspen, while it occurs, is not considered serious since these species have little economic value in the area of gypsy moth infestation.

Mortality occurs to trees of all sizes. However, in assessing mortality losses in this study only those occuring on dominant, co-dominant or intermediate trees have been considered. Death of trees in the suppressed class or which for one reason or another could not have been expected to survive regardless of the gypsy moth have not been used in computing volumes.

Although salvage is theoretically possible in stands badly damaged by the gypsy moth, in practical terms it is rarely carried out. Occasionally, where a stand of high value and size and good accessibility has been killed, some of the timber has been salvaged. In cases where demand for cordwood is high some is cut before it deteriorates too much. However, death generally occurs over a few years and is not always too clearly marked in the early stages. By the time death on a large enough scale to justify salvage has occurred, much of the timber is no longer suitable for lumber. Cordwood in particular deteriorates so fast that unless of large size it is practically worthless a year after death occurs.

In addition to the above factors, the market for oak sawlogs is so selective and for cordwood so limited that even if an owner is in a position to salvage his killed timber he cannot always be assured of a profitable market for the limited period he has to log his timber.

For these reasons no salvage value has been considered in computing the timber volume and value lost through mortality from gypsy moth.

2. THE PROBLEM

It was apparent in studying the problem of losses to timber that insufficient data were available to permit statistically valid conclusions on the monetary values involved. Some excellent basic work has been done on mortality and growth losses for specific areas and periods which have provided a good starting point. However, the system of annual reporting of gypsy moth damage is based on acreage by various degrees of defoliation from 25 to 100%. It was not designed to evaluate actual timber losses. Therefore, no clear relation was found whereby the basic research on mortality and growth loss could be related directly to the annual defoliation records and which could then be used to develop really accurate loss figures.

If accurate evaluation of losses is expected to be a major consideration in formulating policies in future years, there is need for either a revised system of reporting annual defoliation or additional basic research, or both, to develop a better method of relating defoliation with mortality and growth losses. Some suggestions for achieving this are given later in this report.

In view of this situation, it would have been highly desirable to have carried out an intensive program of field investigation to supply needed data and to relate them to the records available. This would have required at least a year of detailed work. Since the time available was considerably shorter than that, it was necessary to make the best use of what basic mortality and growth data there were and to try to work out some formula whereby they could be related to the annual defoliation records and thence to actual timber value losses. The result is an estimate, which if it cannot be backed up entirely by scientifically proven methods, at least represents as close an approach to true damage figures as time and available data permit. Because of the dearth of data and the necessity of relying on more or less arbitrary assumptions supported by opinion if not by fact, every effort has been made to be conservative in handling doubtful relationships. It is believed, therefore, that the estimates arrived at will be found to err on the side of minimizing damage, in the event that future research develops more accurate data and procedures.

The method of investigation pursued involved two main steps. The first was the study of existing data on mortality and growth losses and of the nature of the defoliation records. From this there was evolved a tentative procedure for relating the two. Briefly, this involved the application of a mortality percentage figure derived from existing data to the areas reported annually as 75 or 100% defoliated for the 20-year period. Growth loss percentages were applied to the entire defoliated area in proportion to the degree of defoliation. The acreage of the areas so reported is shown in Table I. Table II portrays the same information in graph form.

TABLE I

GYPSY MOTH DEFOLIATION DATA, 1933-1952 INCL.

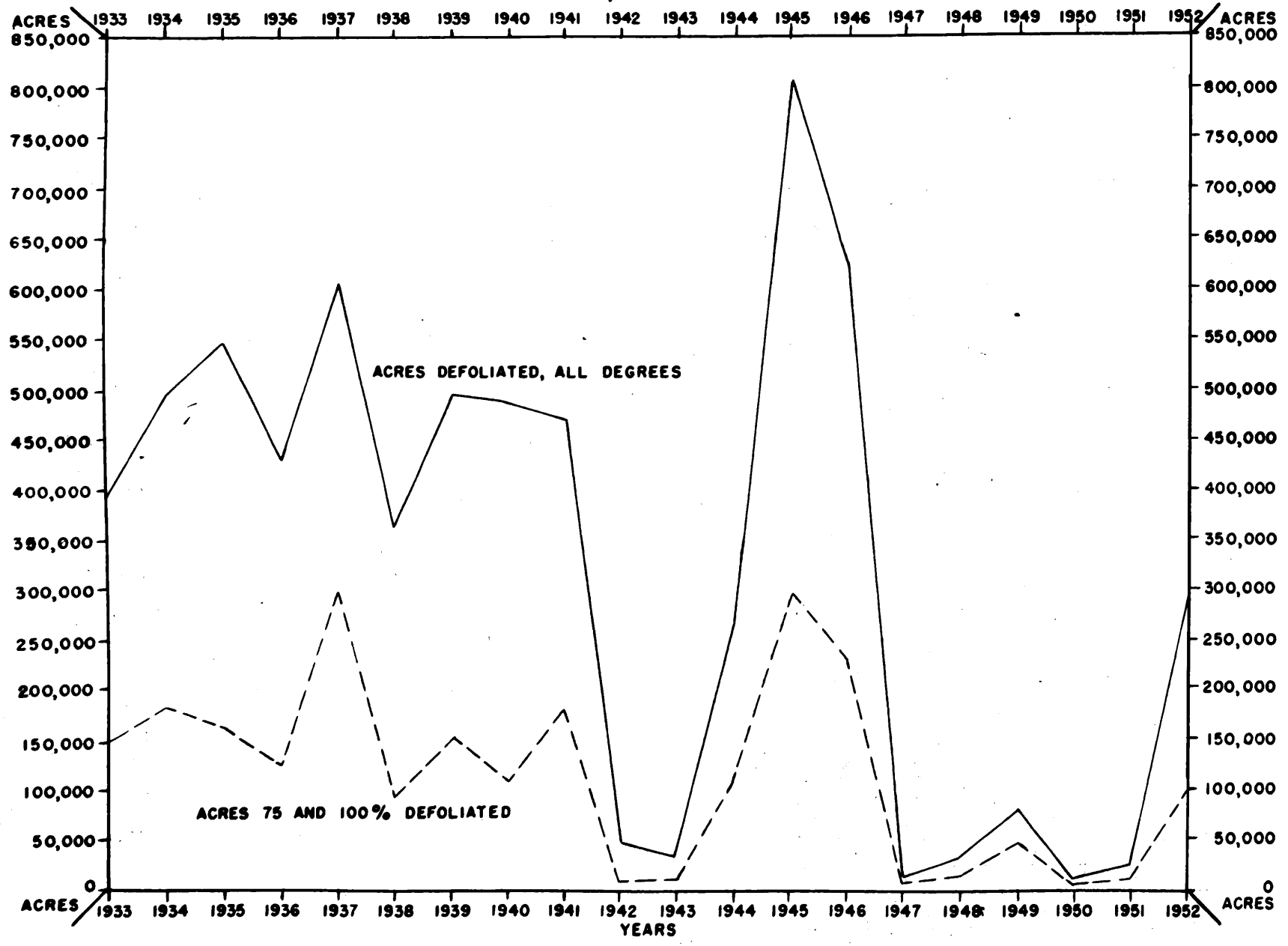
SUMMARY

STATE	No. Acres 75% Def.	No. Acres 100% Def.	Total No. Acres 75 & 100% Def.	% of Total Def. Area that is 75 & 100% Def.	Total No. Acres (All Degrees) of Defoliation	% of Area All Degrees of Def. By States
Maine	218,007	36,327	254,334	15%	1,570,520	24 %
New Hampshire	380,065	87,530	467,595	25%	1,851,820	29 %
Vermont	5,880	3,824	9,704	6%	148,283	2 %
Massachusetts						
Plymouth & Barnstable Co.	241,088	189,978	431,066	51%	858,706	14 %
Other Counties	544,367	586,737	1,131,104	59%	1,944,948	30 %
Total	785,455	776,715	1,562,170	56%	2,803,654	44 %
Connecticut	3,028	4,098	7,126	37%	19,081	.3%
Rhode Island	15,755	3,695	19,450	41%	46,641	.7%
TOTALS	1,408,190	912,189	2,320,379	36.4%	6,439,999	100 %

TABLE II

ACRES DEFOLIATED IN NEW ENGLAND, 1933 - 1952.

75 AND 100%, AND ALL DEGREES.



The second step involved the examination of 84 areas representative of repeated heavy defoliation and characteristic of those appearing on the annual records as 75 and 100% defoliated. As a result of this examination as well as consultation with State and Federal entomologists and foresters, some modifications were made in the procedure originally worked out for determining damage. Also, estimates were made on the spot of mortality, stand volumes, and stumpage values in order to check computations and to reach average figures applicable to the defoliated areas. The field examination also provided an opportunity to gain a better understanding of some of the intangible values affected by gypsy moth defoliation.

Assessing of tangible damage logically can be broken down into three main groups--loss of timber due to mortality, loss of growth, and damage to white pine reproduction.

3. MORTALITY LOSSES

(a) Mortality Percentages

Killing of trees following repeated heavy defoliation is one of the most spectacular results of gypsy moth damage and one to which definite values can be ascribed.

Assessing the part played by the gypsy moth and that played by the two-lined chestnut borer (Agrilus bilineatus, Weber), by diseases, overmaturity, prolonged drought, and frost damage, presents real problems. A detailed breakdown of mortality from these causes is beyond the scope of this study and it is difficult to see how such would be possible without vastly more research. The approach used in this study has been that of a majority of the entomologists consulted and developed in the literature on the subject--namely, that in areas of heavy repeated gypsy moth defoliation the moth is in most cases the primary element in causing mortality. The extensiveness of mortality is often greatly increased by the above factors, a good example being the weakening of the trees by drought and disease. Another example is the occurrence of a late frost previous to a heavy defoliation causing in effect two defoliations in the same year. The basic study used in developing mortality percentages was by George C. Tierney (1) and followed this line. It was also followed in the field inspection phase of the present study where data were recorded only for areas where heavy gypsy moth defoliation was known to have occurred repeatedly over a period of years.

A comprehensive study of mortality and growth losses was made from 1912-21 in eastern Massachusetts and New Hampshire and southwestern Maine by J. N. Summers and others. This was reported in an unpublished manuscript in 1932 (2) and by C. W. Minott and I. T. Guild (3) and later by W. L. Baker (4). The study was based on careful observation of over 186 areas considered representative of the infested area at that time. A mortality loss of 33.13% was found over the 10-year period, making an annual mortality loss of 3.31%. Despite the basic soundness of this study it was so far removed in time from the 1933-52 period covered by this report as to cause doubts as to whether it was applicable to present day conditions. Also there is evidence that killing during the early years of heavy infestation is greater than after the pest has been long established. In addition

no clear determination was possible as to how representative the 186 plots were of conditions throughout the 1933-52 infested area.

A later work carried out by G. C. Tierney in 1947 (1) in the Connecticut Valley area of Massachusetts offered a better chance of correlating mortality percentages with conditions in the past two decades. It also permitted use of the detailed defoliation records of the past 20 years in a more accurate portrayal of recent damage. His data have therefore been used as a basis for the current estimates. His study was based on 34 areas totalling 2,734 acres on which detail history of degrees of past defoliation by years was available for the period 1935-46. For each of the areas this history was given along with the percentage of mortality estimated by him in 1947. Since one of the areas did not have detailed information comparable with the others only 33, totalling 2,584 acres, were used in computing percentages.

Examination of Tierney's data reveals that mortality ranged from 15 to 60% on individual areas varying from 4 to 1000 acres. The average mortality for the entire 2,584 acres when weighted to adjust for the acreage of the individual areas, was about 37%--a remarkable correlation with the Summers 10-year mortality loss of 33.13% in a different area and almost 20 years earlier. The pattern of annual defoliation reported for each of the areas shows defoliation of 75 or 100% on two successive years in the 1944-46 period for all but 5 of the areas. On these five there was only one year of 100% defoliation. From 1939-44 there was a period when practically no defoliation was reported. From 1935-39 varying degrees of defoliation occurred on the areas, but on all it was much less severe than in the 1944-46 period. The high incidence of 75 and 100% defoliation suggested that a practical relationship might exist between the effect of the gypsy moth on Tierney's study areas and on those defoliated 75 and 100% elsewhere in the infested area.

In the 1935-46 year period the average number of years during which 75 or 100% defoliation was recorded for each of Tierney's areas was 2 years. In other words, a mortality of just under 37% resulted from an average of 2 years (some widely spaced--others successive) of 75 or 100% defoliation. If the relationship between conditions on Tierney's areas and on all areas having 75 or 100% defoliation were a direct one, it could be assumed that one year's defoliation of either 75 or 100% would cause half as much mortality as occurred in two years--or approximately 18%. If the above were correct this figure then could be applied to all acres in the New England States that were 75 and 100% defoliated from 1933-52.

Inspection of 84 representative heavily defoliated areas during the field phase of the current study has provided some indication of the relation between Tierney's damaged areas and those elsewhere. The areas inspected during this phase were selected because they were known to have had a history of heavy defoliation over a long period of years and as nearly as possible, to be representative of areas shown as 75 or 100% defoliated in the annual reports. These areas were all within the region of past heavy infestation and were not in the fringe areas experiencing defoliation now for the first time. Estimates of the mortality evident on these 84 areas were made for each one and varied from zero to (in rare cases) 100%. The average for all of them without weighting for the acreage involved in each was 24% mortality. It is probable that these areas suffered from 75 to 100% defoliation, and the average annual mortality was between 12 and 18%.

Although the unweighted average of mortality percentages on the areas inspected was slightly lower than that found by Tierney, it was clear in the present study that it was not always possible to actually appraise the full extent of damage that occurred early in the 20-year period. Some of the evidence was lost in stems that had disappeared and even holes in the crown canopy had become partially filled up. Consequently it is believed that the percentage mortality losses derived from Tierney's study based as it was on detailed knowledge of specific areas can safely be applied to the majority of the areas defoliated 75 or 100% and still be conservative.

An exception has been made in Connecticut and Rhode Island where, as it has been demonstrated to the writer by men familiar with the problem, a degree of resistance exists which even in years of heavy buildup causes the mortality losses to be considerably under the average for other areas of New England. To approximate this difference a mortality percentage of one-half the 18, or 9%, has been used for Connecticut and Rhode Island.

The net result of the above is that in this study it is believed that on the average for every acre reported as 75 or 100% defoliated in the last 20 years, a mortality primarily due to gypsy moth of 18% of the volume occurred. This does not disregard the effect which many intervening years of 25 or 50% defoliation, however slight, may have had since the effects of these years has combined to produce the results observed in Tierney's mortality study and in the examination of defoliated areas made in connection with the current study.

It should be emphasized at this point again that insufficiency of data which could be applied directly to defoliation records has required the making of many arbitrary decisions based on judgment alone which may well be open to question. They have been made, however, on the best available evidence today. While this writer takes chief responsibility for them they have the general approval—lacking more definite data—of a majority of the entomologists consulted.

(b) Stand Volumes

Having derived an expectable mortality loss of 18% it was necessary to find out to what stand volume this applied so as to determine how many cords or board feet have been lost through killing. Two main problems were evident. The first was to establish a volume per acre which would be a reasonably accurate expression of average stand conditions in the areas of heavy infestation—i.e., the areas defoliated 75 or 100%. It was obvious after very little field work that there was considerable variation in the stand volumes among the 6 states covered and enough variation in Massachusetts to indicate that the two southeastern counties—Plymouth and Barnstable—should be treated separately.

Since the U. S. Forest Survey is incomplete at present for all of New England, no exact figures are available, but preliminary estimates suggest that in the oak types of New England the average volume per acre is probably under 2,000 board feet or 10 cords per acre in trees 6 inches dbh. and larger. A study made by A. H. Hawes in 1935 of the town of Eastford, Connecticut estimated the hardwood stands in the town, mostly oak, at about 12.5 cords per acre. Other average estimates for different areas over the years range between these figures with some higher.

The actual volume figures used in the current study were derived from estimates made in examination of the representative heavy defoliated areas in the six states. They agree generally with informal estimates of foresters and others consulted during the course of this study. The volumes per acre used for each state are listed in column 3, Table III. Volumes of mortality per acre and total are given in columns 5 and 6. In making these inspections, volume per acre estimates were made of board feet in trees of size and quality for saw logs, poles or piling above 12 inches dbh, and for additional cord wood material in tops or defective trees and in smaller timber down to 4 inches where cordwood material existed. They have been corrected by the percentage of mortality evident to reflect an approximation of the volume per acre present when mortality commenced. As an example, if an area was estimated to have 4 cords per acre when inspected in 1952 and the mortality was estimated at 50%, it was considered to have containe 8 cords per acre at the time killing by gypsy moth began. It is the average of these corrected figures which has been used in determining an average volume per acre loss in the areas 75 or 100 percent defoliated.

In general, the areas of heavy repeated defoliation and damage examined were characterized by poor site conditions with relatively open stands of lower volume and quality than average over the entire oak area. This bears out the conclusions presented in a detailed study of site conditions and gypsy moth infestation made in a recent Harvard Forest Study by Bess, Spurr and Littlefield (5). Poor site conditions were especially evident in the southeastern counties of Massachusetts and throughout much of that state as well as considerable areas in Maine, New Hampshire and Vermont. In the latter states, however, there were substantial acreages of oak timber apparently running originally to 15-20 cords per acre including substantial volumes of saw timber heavily damaged and with a heavy volume loss per acre. This condition plus the smaller areas of light open timber characterizing much of the Massachusetts area is represented in the higher average volumes per acre used for the three northern states.

Stand conditions were found the lightest in Plymouth and Barnstable Counties and volumes were frequently so low as to be insignificant in terms of timber values.

Just how much of the poor site and stand conditions found over the majority of the heavily defoliated areas is due to gypsy moth damage and how much to past land abuses such as depleted soil, overgrazing, heavy cutting or fire is impossible to determine. They are often interrelated, and in the case of fire and gypsy moth infestation, breed conditions favorable for repeated visitations by both. Despite this uncertainty it is now clear from current and past observations that repeated attack by the gypsy moth has been a major factor in the mortality of these stands and in keeping them to a lower stand volume than in the uninfested areas or in the areas of better site conditions.

The second problem involves the impossibility of determining exactly what the original stand volume was. In areas where gypsy moth infestation has been of long standing occurrence it is impossible to estimate exactly what the volume per acre was since much of the mortality from many years back is evident only from holes in the crown canopy—the stems having long since disappeared. A partial correction for this has been made as outlined above by applying estimated

TABLE III

ESTIMATED MORTALITY LOSSES FROM GYPSY MOTH TO MERCHANTABLE TIMBER IN THE NEW ENGLAND STATES 1933-1952

STATE	(1) No. Areas Examined 1952	(2) Acres Defoliated 75 & 100%	(3) Est. Volume per Acre before Mortality	(4) Mortality Percentage	(5) Mortality Volume per Acre	(6) Mortality Total Volume	(7) Est. Stumpage Value per Cord M b.f.	(8) Est. Value Stumpage Killed	(9) Total Value Stumpage Killed
Maine	12	254,334	9C .75Mbf	18	1.62C .135 Mbf	412,021C 34,335Mbf	$ 1.50/C 12/Mbf	$ 618,031 412,020	$1,030,051
New Hampshire	16	467,595	7C .5Mbf	18	1.26C .090Mbf	589,170C 42,084Mbf	1.50/C 12/M	883,755 505,008	1,388,763
Vermont	6	9,704	8C .5Mbf	18	1.44C .090Mbf	13,974C 873Mbf	1.50/C 12/M	20,961 10,476	31,437
Massachusetts									
Barnstable) Plymouth Cos.)	19	431,066	3C	18	.54C	232,776C	.50/C	116,388	116,388
Other Counties	26	1,131,104	5C .25Mbf	18	.90C .045Mbf	1,017,994C 50,900Mbf	1/C 12/M	(1,017,994) (610,800)	1,628,794
Total All Mass.	45	1,562,170							1,745,182
Connecticut	5	7,126	8C .5Mbf	9	.72C .045Mbf	5,131C 321Mbf	2/C 12/Mbf	10,262 3,852	14,114
Rhode Island	—	19,450	5C .25Mbf	9	.45C .0225Mbf	8,753C 438Mbf	1/C 12/M	8,753 5,256	14,009
TOTAL	84	2,320,379				2,279,819C 128,951Mbf		$2,676,144 1,547,412	$4,223,556

mortality, evident in standing or down dead trees, to the current volume to get the volume as of the beginning of damage. However, this obviously does not cover cases of heavy damage in the early 30's where accurate evidence of heavy mortality is no longer visible. Since no method of completely correcting for this factor is evident, it is one more indication that the overall loss figures presented by this study are on the conservative side.

(c) Stumpage Values

As noted above, estimates of stumpage values were made on each of the heavily infested areas inspected. These were made in the light of the writer's experience as an appraiser and as a buyer and operator of stumpage. Where possible they were checked with individuals familiar with conditions in specific areas or, lacking that, with average conditions throughout the state. These reflected size and quality of the timber, volume per acre, logging chance and accessibility.

Like stand volumes, the stumpage values on heavily defoliated areas ran lower than the average for the oak types and for almost the same reasons. The only additional factors not reflected in stand estimates were logging chance and accessibility. Many of the areas inspected were on rough ground, hill tops or at some distance from existing roads. These conditions nearly always coincided with low volumes per acre.

On some areas such as Barnstable and Plymouth Counties in Massachusetts, and in parts of southern Maine, New Hampshire and Vermont, stumpage values were only nominal, and were evident at all only because there was growing wood, the future value of which could not be completely discounted. On many of these areas current stumpage value was actually nil, bringing down the average, but in almost all cases some value was ascribed, however low, to take into account some expected timber value in the future. In the case of Plymouth and Barnstable Counties it requires considerable imagination to ascribe any real stumpage value to the thousands of acres of stunted low quality oaks. However, drastic changes in northeastern hardwood markets in the past ten years suggests that it is unwise to completely discount any growing wood values. Hence the very nominal value of $.50/ cord put on oak stumpage values in these areas. This is a reflection of the poor conditions noted above, influenced upward by the small amount of sawtimber values. Because of the small proportion of these--mostly held in connection with residential areas--they have been lumped with cordwood values, slightly raising the average.

The next higher values are placed on Rhode Island and the remaining counties of Massachusetts of $1/ cord and $12/M for saw timber. The $1/ cord is a reflection of the large areas which have better growth and quality possibilities than those of Cape Cod, but which still have low current value and limited potentialities in the foreseeable future. These values are characteristic of the hilltops and ridges of the Connecticut Valley and eastward where much of the damage in these parts of Massachusetts has occurred.

In Maine, New Hampshire, Vermont, and in the small areas heavily damaged by the gypsy moth in Connecticut, little difference was found in average estimated stumpage values, and the value of $2/ cord for trees under saw timber size has

been used in these areas. This is a reflection of considerable areas where the stands under saw timber size have real future value as saw timber in addition to nominal value as cordwood, pulpwood and boltwood. As noted above, there are areas of as low values as Massachusetts, but on the average, quality and potential values appear much higher for the areas of heavy gypsy moth defoliation in these states.

Stumpage value of oak, of saw timber size, has been placed at $12/M which was about the average for all damaged areas where there were saw timber values. This lies below the mid-way point of the 8-20 dollar stumpage range often quoted for this species and is a reflection of lower than average sites and quality as well as accessibility and other physical factors affecting stumpage value. It takes in both the high values where oak can be used for poles and piling as well as the lower values where it has only marginal stumpage value.

Computing by the above methods results in a loss for the past 20 years of 2,279,819 C. and 128,951 Mbf of merchantable timber having a total value of $4,223,556. This loss occurred on the 2,320,379 acres that have been defoliated 75 or 100% in that period, but actually covers a much smaller area since in many cases--which are indeterminable--the same area may be reported in different years with repetitions of these degrees of defoliation.

A breakdown of volumes and losses by states as well as the mortality percentages, volumes per acre and stumpage values used is shown in Table III.

4. LOSS IN TIMBER GROWTH

Loss in diameter growth due to gypsy moth defoliation is a much less spectacular manifestation of damage than death but an important one as far as timber production is concerned. It is apparent only when logs have been cut or borings made, or on long continued observation of the development of a stand. It is not uncommon to hear reference made to a stand which has "looked the same for 20 years". On many it is evident that there has been no net growth at all even where actual mortality is low.

Comprehensive studies were made of growth losses in eastern New England in the 1912-21 year period and reported on in the references cited (2)(3)(4). These were based on study of increment borings in test areas over a period of years for which the exact defoliation history was known for each one. Minott and Guild (3) found that growth decreases as defoliation increases in practically constant ratio and concluded that ".....with the oaks of New England an average loss of one-third the foliage per year results in a loss during a ten year period of one-third the normal diameter growth of timber". Or put another way, in the words of J. N. Summers (2) ".....the percentage of annual defoliation results in an equivalent annual retardation of growth".

As in reaching estimates of mortality the value of these good basic data is limited by the fact that the yearly defoliation records give no idea of the defoliation history of individual areas, i.e. what the average defoliation on an acre actually was. This makes it impossible to apply the above principles directly for an accurate evaluation. As before, it is necessary to make some arbitrary decisions based on judgment rather than on fact.

J. N. Summers, in projecting the growth loss data from the individual areas studies from 1912-21 to the larger infested area from 1924-31, devised a method which appears reasonable and which, in the lack of anything more accurate, has been used in this study. This was to use the average defoliation percentage reported for the entire area over the period of years as the percentage loss in growth on each acre defoliated.

This method is based on the assumption that for practical purposes the net result of a year's defoliation to a given percentage on one acre is the same percentage loss of what would have been normal growth on that acre. In actual fact this is not true for specific years as shown by Baker(4)(p.1019). In borings taken in a large number of trees over the 1912-21 year period the percentage growth loss was found to be considerably lower than the average annual defoliation percentage for that period. Even in the case of 81-100% mean annual defoliation the increment loss was found to be only 58% on oak trees. However, it is reasonable to assume that the retarding effects on growth of feeding--especially in the heavier degrees--are felt beyond the year in which feeding actually occurred even if feeding does not occur every year, and in the absence of average defoliation figures to use on individual acres the use of the average defoliation over the entire area should give an approximation of the actual growth loss.

The average weighted defoliation percentage for the 6,439,999 acres defoliated in all degrees in New England from 1933-52 was found for each state and is listed in column 2, Table IV. It is assumed that on each of these acres there was a growth loss equivalent to the average defoliation percentage found for each acre defoliated.

These average defoliation percentages were derived by averaging the total acre-years in each defoliation class and weighting by the number of acres reported in each class for every year. Thus, in the case of Maine the average percent defoliation was found to be 35.6% for each of the 1,570,520 acres that were reported defoliated in all degrees. Reference to the graph in Table II will show some of the relationships between the different classes of defoliation.

Defoliation percentages appearing in the annual records actually cover a range of values--thus what appears as 100% defoliated on the annual records, means that for a particular area and year in the estimation of the reporter, the defoliation was between 76 and 100%. Similarly, what appears as 50% actually covers the range from 26-50% and similarly for all the classes. In averaging these percentages, therefore, a mid-way point was taken for each range as representing the average degree of defoliation reported for that range. The value of 87.5% was taken for the range represented by 100% defoliation, 62.5% for 75% and 37.5% for the range represented by 50%. An exception was made in the lowest range represented by 25% where it was felt that no defoliation under this percentage could have been detected. Therefore, the value of 25% was retained for this range.

Determining normal growth rates for any timber type is difficult and the oak types are no exception. From study of available references and consultations with a number of New England foresters 1/2 cord per acre per year has been set as a reasonable figure to use as normal growth in the oak types without interference by gypsy moth. Applying the percentage of growth loss found for each

TABLE IV

ESTIMATED LOSSES IN GROWTH FROM GYPSY MOTH TO TIMBER IN THE NEW ENGLAND STATES 1933-1952

STATE	(1) Area Def. all Degrees	(2) Avg. Percentage Def. for 1 Yr. per Acre Def.(a)	(3) Avg. Est. Growth Loss for 1 Year per Acre Def.	(4) Normal Est. Growth Rate per Acre per Year	(5) Loss in Growth for 1 Yr. per Acre Def. Cords	(6) Total Loss in Growth for Area Def. Cords(b) (Col 1x5)	(7) Value per Cord(c)	(8) Value of Growth Loss	(9) Value of Mortality Loss (Column 9) (Table III)	(10) Combined Value Mortality & Growth Losses
Maine	1,570,520	35.6%	35.6%	.5C	.178C	280,000C	$2.00	$560,000	$1,030,051	$1,590,051
New Hampshire	1,851,820	39.9%	39.9%	.5C	.20C	370,000C	2.06	762,200	1,388,763	2,150,963
Vermont	148,283	31.4%	31.4%	.5C	.157C	23,200C	2.00	46,400	31,437	77,837
Massachusetts										
Barnstable & Plymouth Counties	858,706	52.7%	52.7%	.5C	.264C	227,000C	.50	113,500	116,388	229,888
Other Counties	1,944,948	57.0%	57.0%	.5C	.285C	554,000C	1.64	908,560	1,628,794	2,537,354
Total	2,803,654					781,000C		1,022,060	1,745,182	2,767,242
Connecticut	19,081	46.5%	46.5%	.5C	.232C	4,400C	2.50	11,000	14,114	25,114
Rhode Island	46,641	46.7%	46.7%	.5C	.234C	10,900C	1.64	17,876	14,009	31,885
TOTAL	6,439,999					1,469,500		$2,419,536	$4,223,556	$6,643,092

(a) Derived from averaging all the percentages of defoliation reported and weighting for the number of acres in each for each of the 20 years.

(b) Even hundreds.

(c) Obtained by incorporating mbf/acre stand volumes and values into cord volumes and values per acre.

state as above to 1/2 cord the loss per acre is found to vary from .157 cords to .285 cords for the entire defoliated areas in each state. Values of saw timber and cordwood have been merged into cordwood values in computing stumpage values for each state. Cognizance, however, has been taken of the variation in volume and value of cordwood and saw timber considered to have existed per acre before damage. This gives a different stumpage value per cord for each of the states since in some, as in Connecticut, the volume of saw timber in addition to cordwood is estimated as greater than in others such as Massachusetts where both the volumes are less and the proportion of saw timber to cordwood is lower. The values given vary from $.50 to $2.50 per cord.

The total volume growth loss found by the above methods for all the New England States from 1933-52 is found to be 1,469,500 cords with a value of $2,419,536. This is shown in columns 6 and 8, Table IV. In column 9 the values found for mortality losses are recapitulated (from Table III) and in column 10, the total estimated losses from both mortality and growth losses are given as $6,643,092.

5. MORTALITY TO WHITE PINE

Although white pine is not a favored food species for the younger stages of gypsy moth larvae it is sometimes favored by the larger stages, and in areas of extremely heavy feeding stripping of white pines and even of hemlock is not uncommon.

It is often heard that a single complete defoliation of white pine will cause death, but this is not necessarily always the case. Studies carried out from 1915 to 1924 and reported on by Baker (4) showed that even the higher degrees of defoliation did not, on the average, cause anything near 100% mortality. Most of the 310 pines observed in the study were defoliated less than 60%, but the 59 which suffered from 81-100% in 1915 showed only a 32% mortality by 1924. Pines defoliated to lesser degrees showed far less mortality.

In the course of the field phase of the current study a number of cases were observed where mature pines and hemlock had been killed following heavy defoliation. The volumes and values involved in killing of merchantable pine and hemlock have been included in estimation of losses due to mortality of merchantable oak timber already outlined, and therefore do not warrant separate treatment.

Of greater possible importance is loss of white pine in the reproduction and intermediate classes due to gypsy moth defoliation. Evaluation of damage is complicated by other factors which affect the ability of white pine reproduction to succeed when overtopped by hardwoods. Observation in the field suggested that defoliation of pine in the understory was not uncommon in the pine-oak types, but in most of the cases observed there was considerable question whether the pine would have survived through normal suppression.

To draw on the accumulated experience and observation of men familiar with field conditions, a questionnaire was sent to 50 foresters and entomologists in the New England area requesting their estimate of the seriousness of white pine mortality in reproduction, immature, and mature classes. Forty-one replies were

received. Of these 34, or a little over 80%, reported no damage known to the individual writers. Of the 7 who reported some damage, 4 based their comments on specific cases of very small acreage. Three reported substantial percentages of white pine killed with no qualifications as to size of area or seriousness as a whole.

Recognizing that even the best-worded questionnaire could not be expected to yield a definitive answer to so difficult a question, it is apparent that the majority of those contacted do not believe that damage to white pine reproduction is of too serious a nature.

However, it is evident from past records and reports and from conversations with men long familiar with gypsy moth work that killing of young pine has been serious on some areas observed in the past 20 years. These observations give little indication of the total acreages involved or the chance which the pine would have had in surviving natural suppression and therefore of the role actually played by the moth in its destruction. Therefore, while there is no clear evidence of the extent of large-scale destruction of pine reproduction the convictions held by a considerable number of men long associated with gypsy moth work bear considerable weight. It is clear that damage to pine reproduction is of a type which is not always readily evident. Pine reproduction disappears so fast after death from any cause that only the most detailed observations could properly appraise the role gypsy moth has played in death.

In view of the above, it is considered that the evidence available in this study is not entirely conclusive. Detailed field studies of the problem will be necessary to develop a clearer relation between gypsy moth damage and suppression from natural causes and to permit more accurate evaluation of the part played by this insect in mortality of white pine reproduction.

6. INTANGIBLE LOSSES

(a) Damage to Site

An important type of damage which is not adequately represented in estimates of value of timber lost through mortality and decreased growth is the damage done to the forest site by repeated heavy gypsy moth feeding. It is important because it involves other values not readily assessable in terms of dollars and cents, such as watershed protection, recreational and aesthetic values and possibly wildlife production, but which are nevertheless real values.

Of great importance is the continued effect of heavy gypsy moth damage to site, not only during the periods of heavy infestation but between and after them. In combination with past damage by fire, overgrazing, other poor agricultural practices, and overcutting, the gypsy moth has helped to keep large areas in an unproductive condition and to promote further deterioration. The effects of drying out and compacting the soil, destruction of humus by exposure to intense sunlight through light crown canopies and retardation of desirable reproduction reach far beyond the years covered in this study. Even were the gypsy moth completely controlled in the next few years, the effects of this deterioration could be expected to continue for many years in limited production of timber crops and other values which forest land is capable of producing.

Large acreages are now dominated by low value wood which has little foreseeable future value as timber and which will long retard the development of a new and better forest. Due to this deterioration of the site and species as a result of defoliation by the gypsy moth, it should be a long time before conditions are suitable for the better species to become dominant.

Even were it possible to accurately assess the part the gypsy moth has played in relation to the land abuses mentioned above, it would still be impossible to evaluate this type of damage in the same terms as actual timber values that we can see have been lost.

For that reason and because of the widespread and long-continuing nature of the damage already done to the forest resources of this region, the real losses at least equal and probably far exceed those from the more tangible forms of damage assessed in this study.

(b) Aesthetic Damage

Losses in aesthetic and recreational values are harder to pin point than timber losses. In times of heavy defoliation, especially in residential areas and in areas of relatively high aesthetic value, the gypsy moth causes great distress to people who take pride in the appearance of their properties. In addition to losses occasioned from the outright killing of high value ornamental trees irreplaceable over several lifetimes, people just do not like the unsightliness of defoliation and the nuisance of crawling caterpillars invading their homes.

Probably as good an indication as nay of the aesthetic value put on gypsy moth damage is the amount of money which the citizens of the states, counties and towns have willingly voted to raise at their own expense to mitigate the nuisance. It is unlikely that the thinking that made this possible was directed at timber production on the hundreds of thousands of acres of undeveloped land, but rather at controlling damage and nuisance to the shade trees, residential and recreational areas. Such money raised locally is a significant expression of public interest.

Table V shows the amount of money spent by Federal, state, county and town agencies in the United States and also for the Province of New Brunswick and for Canada. Taking New England only, the expenditure of almost $20,000,000 in the last 20 years primarily for local protection suggests some of the importance that people put on the aesthetic values involved in gypsy moth infestation. This includes the $640,330 raised and spent in Barnstable and Plymouth Counties to carry out the widespread DDT spraying program in 1949 and 1950. It does not include the considerable amount spent for spraying by private owners.

Also shown are the amounts spent by New Jersey and Pennsylvania to clean up isolated outbreaks and the $3,142,184 spent to date by New York cn gypsy moth work. These give some suggestion of the desire of the tax payers of those states to avoid a recurrence of what has happened in New England.

TABLE V

Total Expenditures on Gypsy Moth Work

Fiscal Years 1933 - 1952 Inclusive

FEDERAL			$18,435,717
STATES and CANADA			
Maine	$ 479,835		
New Hampshire	646,302		
Vermont	45,030		
Massachusetts	16,888,534		
Connecticut	848,363		
Rhode Island	629,028	$19,537,092	
New York	3,142,184		
New Jersey	247,510		
Pennsylvania	1,776,884		
Dominion of Canada	24,404		
Prov. of New Brunswick	2,116	5,193,098	
STATES and CANADA			$24,730,190
GRAND TOTAL			$43,165,907

7. PROJECTION OF DAMAGE ESTIMATES

An effort has been made in this study to produce a realistic estimate of the timber values affected by 20 years of gypsy moth activity in New England.

This has affected a total of 6,439,999 acre-years, being the total acreage actually defoliated. A much smaller actual area within the infested area is involved, however, since large areas have been defoliated repeatedly and there are corresponding duplications of acreage reported in the annual records.

Computations on mortality percentages, both those of Summers for 1912-21 and Tierney for 1935-46 and the observations during this study are based on areas which have had a history of long heavy infestation. There is evidence that mortality is apt to be higher in the early stages of an infestation in an area previously unaffected. Areas to the west and northwest of the past repeatedly defoliated region, which are now beginning to experience entirely new heavy outbreaks, as well as those areas west of New England into which the moth may spread if not controlled, might show higher mortality percentages than in the area covered by this study.

In projecting per-acre losses from mortality and loss in tree growth cognizance should also be taken of the fact that in many cases in New England these are based on relatively low per-acre volumes and values--the result of a long history of infestation and of land abuses. The latter may be present to a greater or lesser extent in the areas into which the moth is now advancing and into which it may advance in the future, but the potential damage in new areas will at least equal that found for the New England area for the past 20 years.

8. IMPROVED DAMAGE ESTIMATES

The impossibility of arriving at a precise estimate of gypsy moth damage and the problems encountered in arriving at even a reasonable one have been discussed previously. They stem primarily from the impossibility of directly relating data available on growth loss and mortality which are based on average defoliations over the years on the same area, with the annual defoliation records which show only the total acreage observed.

For reasons of time and cost it is probably not practical to revise the system of defoliation reporting drastically enough to permit determination of the number of times and to what severity individual areas have been defoliated.

A more practical and economical approach might be through field studies to determine the frequency and degree of defoliation that could be expected on the same areas for different stand compositions. Enough good work has been done on the relationship of stand composition and site to gypsy moth activity to suggest that some sort of a classification system might be adaptable to establishing such a ratio. If it could be determined what actual acreage on the ground is represented by a period of years of defoliation a long step would have been made toward permitting accurate estimates. The studies already carried out for the northern protion of the Connecticut Valley watershed in Massachusetts where the location of areas defoliated to the different degrees have been plotted on overlays to show the amount of overlapping from year to year might be a good starting

point. Such studies carried out along with other investigations for representative areas within the infested zone would be very useful.

Field studies such as carried out in this study in a limited amount of time, to determine condition, volumes and stumpage values could also be used to good effect for future estimates if more time were allowed so that more areas could be visited and increment borings made.

As a final suggestion to make the annual defoliation records yield more in terms of significant data it may be worth considering the breaking down of areas defoliated into some simple classifications based on timber values. On the annua. defoliation records, 100,000 acres defoliated 100% conveys nothing to the mind but acreage. Yet, in terms of values, there would be an enormous difference depending on whether it was in a ruined area of central or eastern Massachusetts or one of the new areas of western Massachusetts or Vermont with real timber values at stake. Knowing what values are at stake would seem to be more important now with evidence that the past is moving into areas untouched before and potentially of higher value. Even a classification covering only mature saw timber, pole timber, cordwood, and low value scrubland would yield much valuable information and be reasonably simple to use in the field.

SUMMARY

1. The estimates obtained in this study are based on data available from past research on mortality and growth losses due to varying degrees of defoliation and on current inspection of representative heavily defoliated areas to check mortality and to furnish stand volumes and applicable stumpage values in each of the New England States.

2. Estimated tangible losses due to the gypsy moth on forest trees in New England for the 1933-52 period are as follows:

	Cords	Mbf	Value
Mortality Losses	2,279,819	128,951	$4,223,556
Growth Losses	1,469,500	--	2,419,536
TOTAL	3,749,319	128,951	$6,643,092

3. The above estimates of losses do not include the intangible values affected by damage to site and to future production of timber and related forest values. Damage to site over a long period of years in combination with past and current man-caused abuses such as fire and over-cutting has caused and is causing increasing deterioration over large acreages. The effects can be expected to extend far into the future and far beyond any assessable losses to past and present timber values. These intangible losses at least equal and probably far exceed those from the more tangible forms of damage.

4. The estimates of damage are a reflection of the impact of repeated heavy defoliation by the insect on large areas, most of which have had a long past history of defoliation as well as of land abuses. For this reason caution is needed in projecting these estimates of tangible timber losses to the situation that can develop in new areas to which the gypsy moth is moving for the first time or may move in the future. Values in the infested area of New England had already been lowered over large areas at the beginning of the 1933-52 period covered by this study. In addition there is evidence that the effects of the moth in new areas is apt to be far more serious than in old.

5. There is some evidence that damage to white pine reproduction has occurred during the 20-year period, but perhaps not in amount sufficient to warrant considering this pest a primary hazard of pine in mixed stands. It is believed that natural suppression through overtopping in the majority of cases is a far more important hazard to pine even in infested areas. However, there is enough difference of opinion on this point among qualified individuals to suggest that the true answer to this problem lies in further research rather than in studies of as limited a scope as this one has had to be.

6. Aesthetic damage is not convertible into dollars and cents, but the willingness of local and state governments to raise and spend an average of almost a million dollars a year for the past 20 years in attempts at local control is an indication of the nuisance value given to the pest by the public, and a measure of the importance of the control of the insect to the recreational industry in the region.

7. Difficulties of relating past research data on mortality and growth losses to the current system for reporting acreage of moth defoliation indicates the need for either additional research or a revised reporting system, or both, in order to improve the accuracy of future appraisals of damage.

The writer wishes to express his appreciation of the real help and co-operation given to him by the personnel of the Gypsy Moth Control Project of the Bureau in carrying out his part of the appraisal survey. Every necessary facility has been put at his disposal and the work could not have been completed in the time required unless everyone involved had shown the extraordinary cooperation and interest which they have.

He also wishes to thank the many entomologists and foresters from the various State Departments and Universities who have actively helped in the field work or assisted in giving advice and guidance. Their help has been essential in seeking the approaches and finding some of the answers to the many difficult questions raised during the survey and which were beyond his experience alone.

Chesham, New Hampshire
December 9, 1952

William P. House

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